

Water use pattern and yield response of pearl millet in the Deccan Plateau*

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ABSTRACT

The study utilizes 4 years data i.e. 1995-1999 of pearl millet grown during *kharif* season at Solapur ((17.04° N, 75.54° E, 476.5 m.a.s.l.) located in the Deccan plateau. An attempt has been made in this study to compute the crop coefficient, water use and its efficiency which are important for soil and agronomic management. Relationship between the height of pearl millet crop and the ET has been investigated. The dependence of ET on the surface wind has also been found out. The analysis revealed that crop coefficients were maximum during earhead emergence and flowering phases and the consumptive water use gradually increases from the vegetative stage reaching maximum during flowering stage. Date of sowing markedly affects yield and water use efficiency. Under the condition of limited soil moisture, how the date of sowing affects the growth and yield has been explored so as to provide an ideal date of sowing for obtaining optimum yield.

Keywords : Pearl millet, evapotranspiration, earhead emergence, sowing dates

Pearl millet is an important crop in dry land culture in the Deccan Plateau. It has numerous advantages that have made it adapted to these harsh environments; namely, its tolerance to high temperatures, drought, low fertile soils and high growth rate. Pearl millets have low moisture requirement. Complete failure of crop due to limited rainfall is much less frequent as compared with other crops. Millet is capable of producing significant yield using 200 mm of moisture during the growing season (Cocheme and Franquin, 1967).

A knowledge of the influence of evapotranspiration (ET) of the plant during its various stages of growth is important for soil and agronomic management and economic evaluation of irrigation. Studies on water use by pearl millet have been reported (Venkatraman, 1988; Payne, 1997; Jadhav *et al.*, 1999). Das *et al.* (1996) showed that the pearl millet used maximum amount of water during the flowering stage in peninsular India and northwest India.

The objective of the present study is to compute the crop coefficients and water

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Table 1 : Crop information, total water used, rainfall, grain yield and water use efficiency

Year	Date of sowing	Date of harvesting	ET (mm)	Rainfall (mm)	Yield (kg ha ⁻¹)	WUE (kg ha ⁻¹ mm ⁻¹)
1995	2.7.95	14.9.95	276.3	283.6	2494	9.0
1997	8.7.97	28.9.97	180.1	116.9	813	4.5
1998	24.6.98	7.10.98	307.1	996.6	833	2.7
1999	19.6.99	15.9.99	218.0	198.6	1001	4.6

Table 2 : Mean weekly water use (mm) pattern in different phases and (water use %) as a function of total evapotranspiration

Year / Phase	1995	1997	1998	1999	Mean
Germination (0-1 WAS)	11.1 (4.0)	9.4 (5.2)	23.9 (7.8)	21.3 (9.8)	16.4 (6.7)
Vegetative ^{56.8} (1-4 WAS)	38.7 (20.6)	31.4 (21.5)	42.3 (10.2)	42.3 (19.4)	42.3 (17.2)
Earhead Emergence (4-6 WAS)	87.4 (31.6)	55.3 (30.7)	97.7 (31.8)	55.5 (25.5)	74.0 (30.1)
Flowering (6-8 WAS)	81.9 (29.6)	33.1 (18.4)	87.2 (28.4)	46.5 (21.3)	62.2 (25.3)
Grain Formation (8-11 WAS)	30.6 (11.1)	28.3 (15.7)	42.7 (13.9)	36.8 (16.9)	34.6 (14.1)
Maturity (11-13 WAS)	8.5 (3.1)	15.3 (8.5)	24.4 (7.9)	15.6 (7.2)	16.0 (6.5)

use efficiency of the pearl millet and to determine the optimum date of sowing for realising full production potential of the crop. An attempt has also been made to find the dependence of ET on the surface wind by multiple regression approach.

MATERIAL AND METHOD

At Solapur (17° 04' N, 75° 54' E, 476.5

masl) located in the Deccan plateau, pearl millet was grown from 1995 to 1999. Daily meteorological data were recored from Agromet Observatory located close to the field and weekly totals from the date of sowing to maturity were computed. At Solapur the soil is mainly medium black, having field capacity 18 cm, wilting point 9 cm and bulk density 1.26 gm cm⁻³. Here

crops are grown purely on rainfed conditions. The hybrid variety of pearl millet *viz.*, "Shraddha" was grown in the field during 1995 to 1997. In 1996, after sowing, there was inadequate rainfall to allow the crop to complete its growth cycle. As a result, the crop was harvested only as a fodder. This study as such, utilizes only four years data *i.e.*, 1995 to 1999 for "Shraddha" variety.

The ET losses were estimated through gravimetric lysimeter. The lysimeter (1.3 × 1.3 × 0.9 m in size with sensitive dormant type weighing machine of two ton capacity) was sunk in the middle of the crop field on a reinforce concrete structure. Potential evapotranspiration was calculated using Penman's method (Doorenbos and Pruitt, 1977) and crop coefficient (Kc) values were computed by using the formula

$$K_c = ET/PET$$

where ET = Evapotranspiration from lysimeter and PET = Potential evapotranspiration

RESULTS AND DISCUSSION

Evapotranspiration and height of the plant

The relationship between evapotranspiration and plant growth in the field may or may not be linear as it is between transpiration and plant growth in container experiments. This is partly because the fraction of evaporation that does not contribute to plant growth varies throughout the crop life cycle. The progressive increase in ET (Table 2) during

phenological stages of seedling to ear head reflects the progress in plant growth.

The height of the plant and the evapotranspiration (ET) were measured every week from sowing to harvest and a polynomial is fitted between biometric height (X) as independent variable and evapotranspiration (ET) as dependent variable. The relationship is given by

$$ET = 13.567 + 1.483 X - 0.027 X^2 \\ (R = 0.96)$$

The relationship seems to be parabolic in nature (Fig. 1). ET increase is found from 3 weeks after sowing (WAS) and attains peak at 6 WAS, when the plant height was 60 cm. Thereafter ET starts decreasing upto the maturity stage.

Evapotranspiration and mean wind speed

Winds increase transpiration by removing the moist air surrounding the leaves; they decrease transpiration by cooling the leaves. Keeping it in view, the relationship has been examined during the sowing period and the first week of the vegetative growth when surface configuration is still an important factor.

The relation between ET and mean wind speed (Y) in pearl millet during the period is given by polynomial

$$ET = -288.026 + 197.003 Y - 32.815 Y^2 \\ (R = 0.95)$$

where Y = mean wind (mps)

Plotting of evapotranspiration and mean wind (Fig. 2) indicates that the relationship is curvilinear in nature.

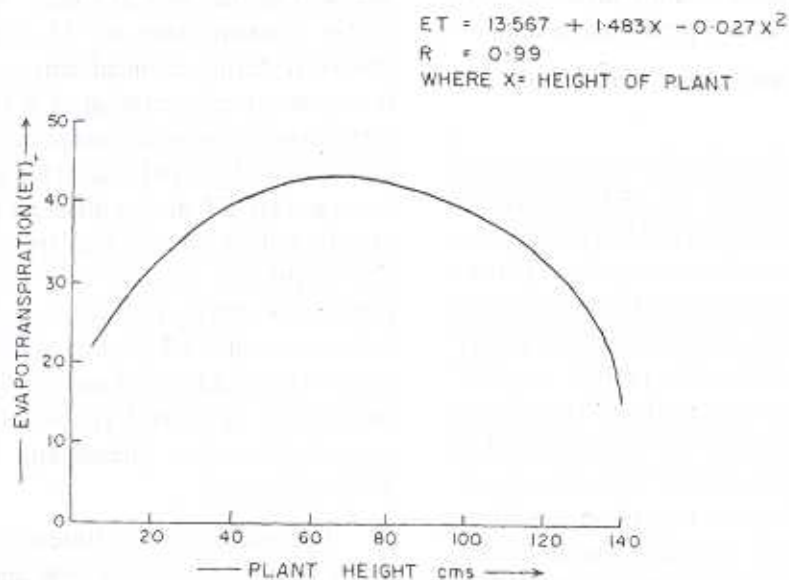


Fig. 1 : Relationship between evapotranspiration and plant height during growing period

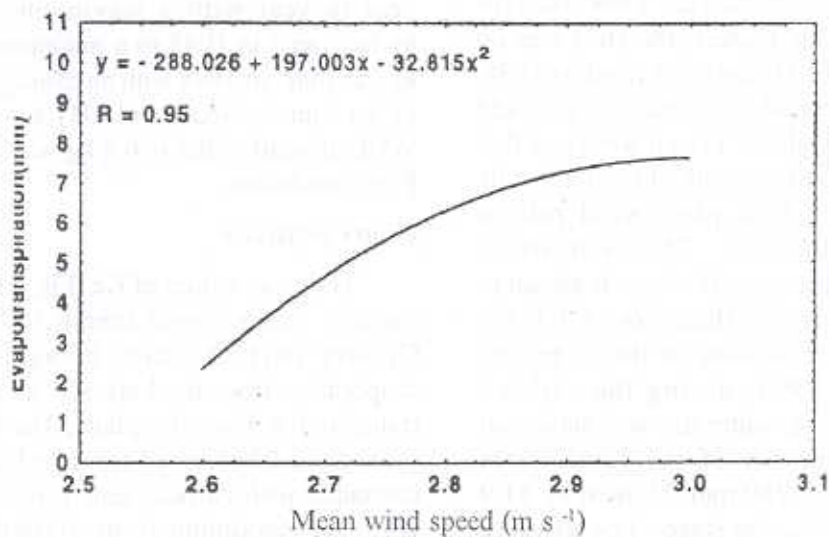


Fig. 2 : Relationship between evapotranspiration and wind speed

Evapotranspiration steadily increases with the increase of wind speed, upto a limit.

Consumptive use of water and water use efficiency

Information on the crop seasonal rainfall and the water use (ET) is given in Table 1 for all the years. The consumptive use of water was seen to vary from year to year and appears to be direct function of rainfall. The higher the rainfall, the higher is the ET loss. When the rainfall was 997 mm, the ET loss was nearly 300 mm in the year 1998, while in 1997 when the rainfall was just 117 mm, the ET loss came down to 180 mm. On an average the crop utilizes 280 mm of water. Similarly, Gupta (1980) obtained water use by pearl millet as 290 mm under control conditions

It is also seen that crop seasonal rainfall does not bear much relationship with the yield. In the year 1998 when the rainfall was the highest, the yield was on the lower side. On the other hand, in 1995, though the rainfall was moderate, the yield realized was highest. Thus it is obvious that it is not the total quantum of rainfall but its distribution which plays vital role in determining the yield. The mean weekly ET for six major growth stages is shown in Table 2. Some differences in ET for different years in some of the stages are evident. In 1995, during the earhead emergence stage, water use was maximum i.e. 87.4 mm out of the total water consumption of 280 mm followed by 81.9 mm during flowering stage. Lowest water use was 8.5 mm during maturity. Total crop

seasonal rainfall was 285 mm. Maximum water consumption of 55.3 mm was observed during earhead emergence, and lowest water consumption of 9.4 mm was seen during germination stage in 1997, and crop seasonal rainfall was 116.9 mm. The mean weekly ET during different phases of growth and its contribution to total water use (Table 2) reveals that during the germination stage, the weekly water used is lowest i.e. about 7 % of the total seasonal water. The weekly water use during earhead emergence is found to be maximum compared to other phases and is nearly 30 % of the total.

The water use efficiency (WUE) serves as a useful tool in crop and variety selection for maximum yield for unit of water consumed. A high seasonal rainfall of 1000 mm need not give higher WUE (Table 1). It is seen that WUE varies from year to year with a maximum of 9.0 kg ha⁻¹ mm⁻¹ in 1995 to a minimum of 2.7 kg ha⁻¹ mm⁻¹ in 1998 with an average of 5.2 kg ha⁻¹ mm⁻¹. Shaikh (1991) found that WUE of pearl millet is 6.3 kg ha⁻¹ mm⁻¹ in Pune conditions.

Crop Coefficient

The mean values of Kc (Fig. 3) during the early stages ranged from 0.20 to 0.60. Greater part of water being lost by evaporation from the bare soil as well as transpiration from the plant. The highest value was 1.03 observed around 6 WAS and coincided with earhead emergence period when the maximum transpiration takes place. Kc fall substantially (i.e. 0.40) at

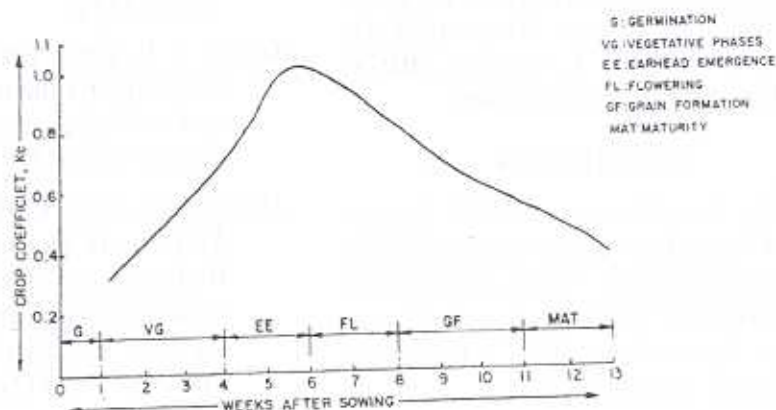


Fig. 3 : March of crop coefficient of pearl millet during the growing period.

maturity due to senescence. Values obtained in the study thus generally agree with those reported by Doorenbos and Kassam (1979) and other research workers.

For normalizing K_c , the crop season was divided into different phases e.g. germination, vegetative, earhead emergence, flowering, grain formation and maturity. The mean value obtained during these phases were 0.30, 0.50, 0.80, 0.98, 0.65 and 0.40 respectively. It is obvious that largest K_c values were attained during the earhead emergence and flowering phases.

Effect of sowing dates on yield

Crop yield is the product of interaction of genotype with environment. As a result, time of sowing also largely determines the crop yield. Sowing of pearl millet is done usually after the onset of monsoon (for Solapur 9th June).

In the present study a polynomial of

third degree was fitted to the yield and date of sowing. For this purpose dates from 15th June onwards (date of sowing) were successively correlated with yield. The dates which gave maximum MCC was chosen resulting in following equation. In these equations, Y represents yield (kg ha^{-1}) and X represents the date.

$$Y = 3833.2 - 403.7 X - 29.65 X^2 - 0.608 X^3$$

($R = 0.96$)

Differentiating Y w.r.t. X and equating it to zero (i.e. $dy/dx = 0$) would give maximum/minimum value of Y for particular value of X . Negative sign of d^2y/dx^2 for particular value of X gives maximum value of Y . The optimum dates for realising full production potential is found to be 7th July and the yield is expected to be about 2800 kg ha^{-1} .

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